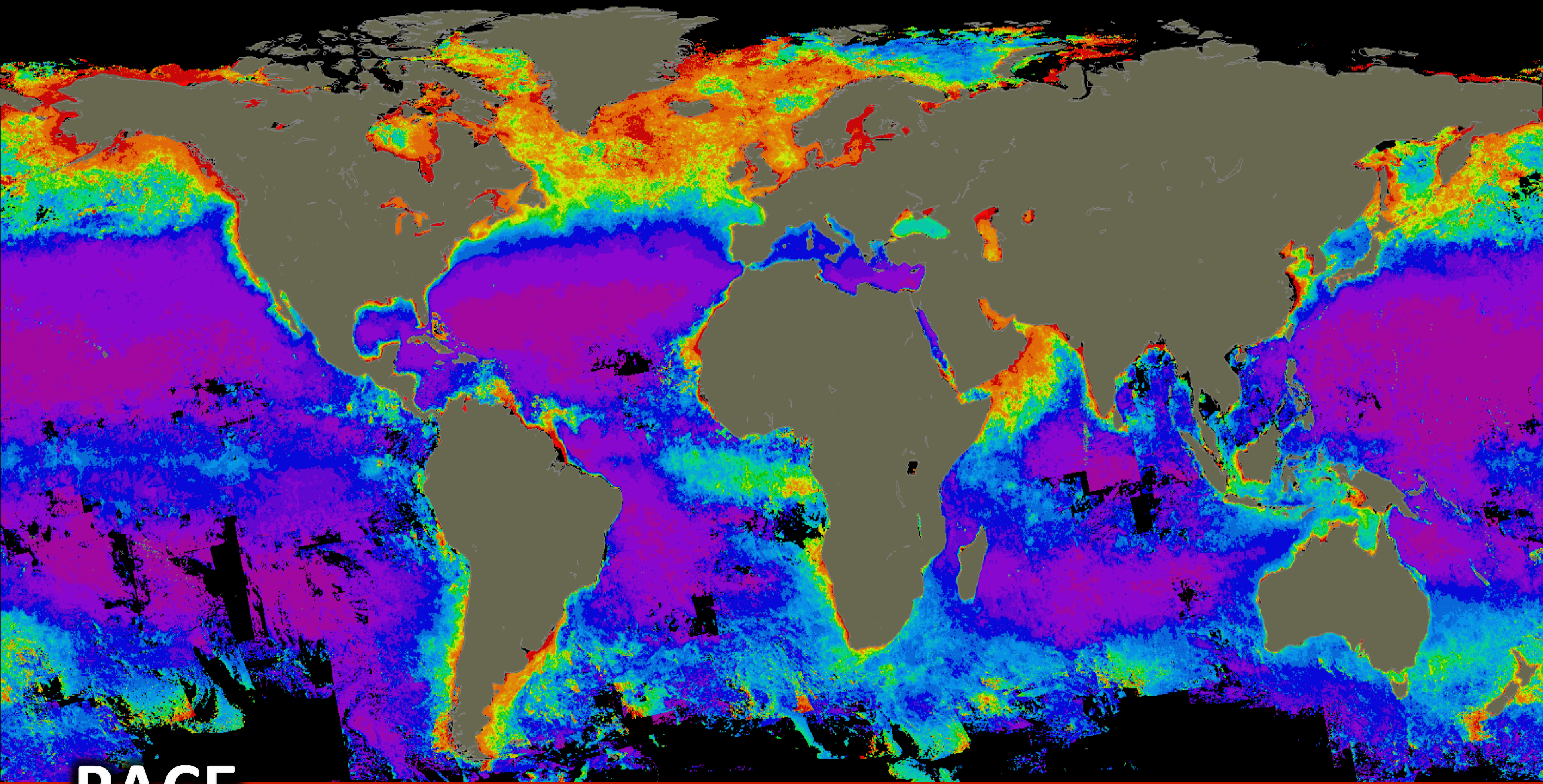
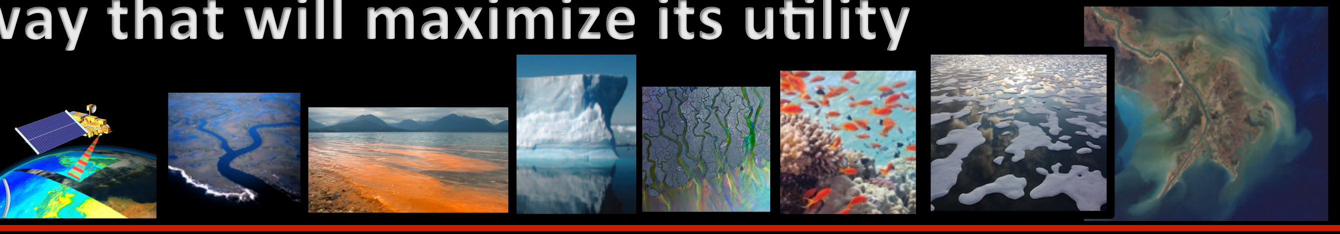


PACE

How can we do our Science in a way that will maximize its utility



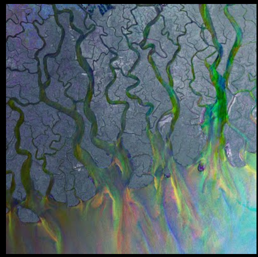
Ali Omar (NASA LARC)
Maria Tzortziou (CCNY/GSFC)

2007 report *Earth Science and Applications from Space: National Imperatives for the Next Decade* (commonly referred to as the Decadal Survey) specifically calls for: ‘societal needs help to guide scientific priorities more effectively and that emerging scientific knowledge is actively applied to obtain societal benefits’

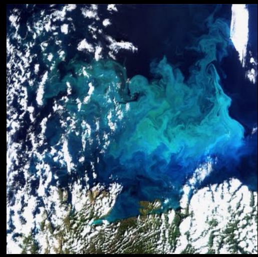
Supply — *Supply of knowledge & information*

Demand — *Need to use this information/knowledge*

“The neglected heart of science policy: reconciling supply of and demand for science”, by Daniel Sarewitz and Roger Pielke, Environmental Science & Policy 10 (2007) 5-16





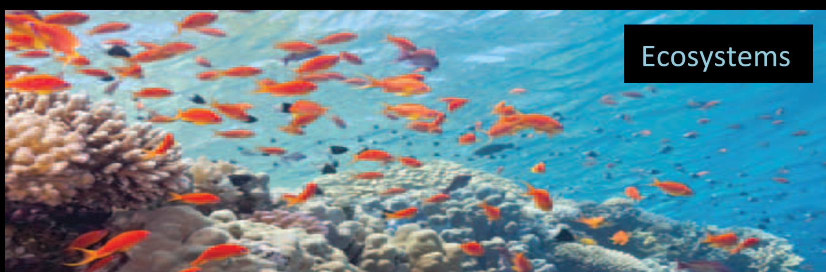

		Demand: Can User Benefit from Research?	
		YES	NO
Supply: Is Relevant Information Produced?	NO	Research agendas may be inappropriate.	Research agendas and user needs poorly matched; users may be disenfranchised.
	YES	Empowered users taking advantage of well-deployed research capabilities.	Unsophisticated or marginalized users, institutional constraints, or other obstacles prevent information use.

Fig. 1 – The missed opportunity matrix for reconciling supply and demand.

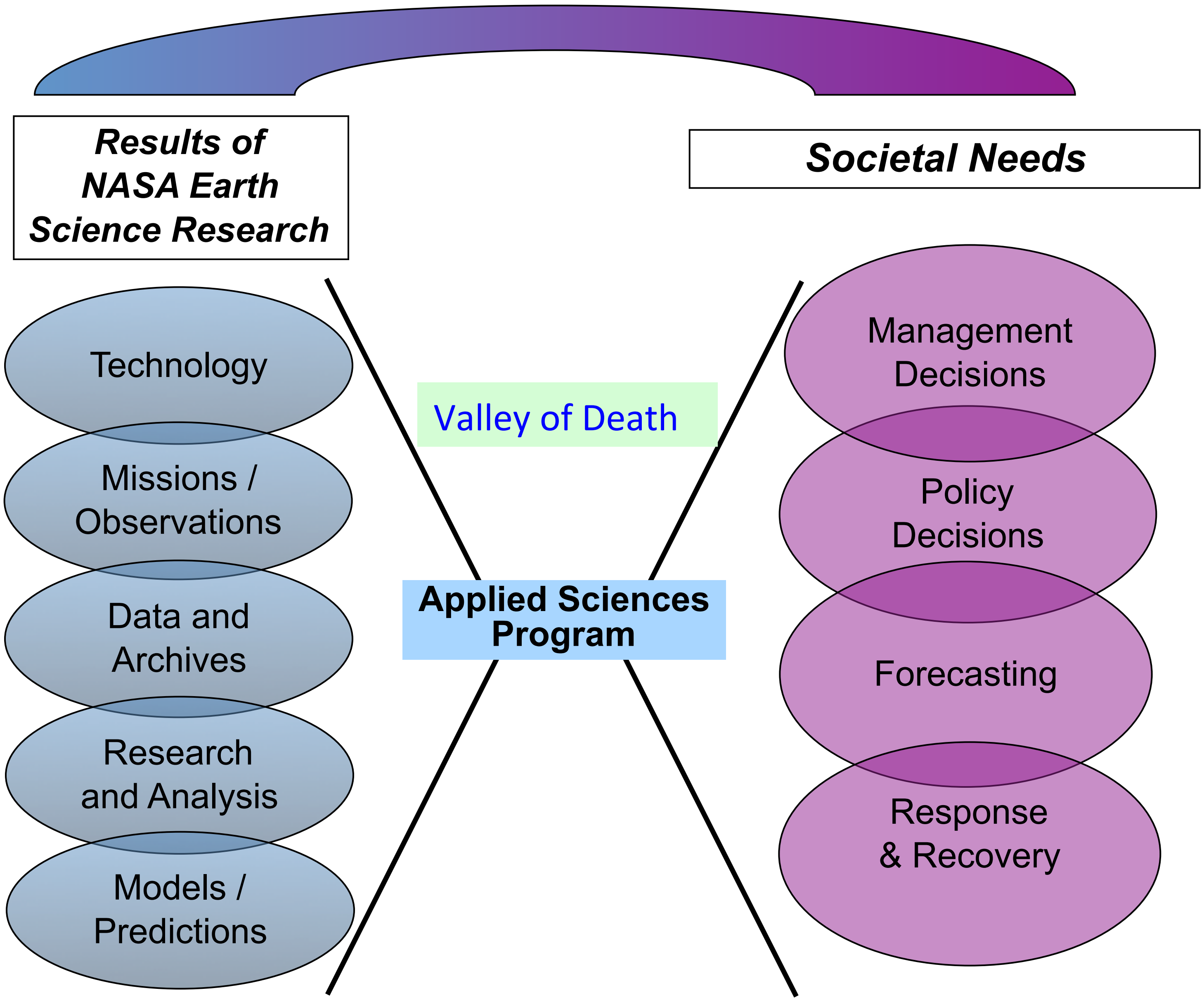
Sarewitz and Pielke, Environmental Science & Policy 10 (2007) 5-16

PACE observations: Utility, Applications ,and Societal Benefits

The NASA Applied Sciences Program promotes and funds activities
that discover and demonstrate innovative uses and practical benefits of NASA's Earth science resources

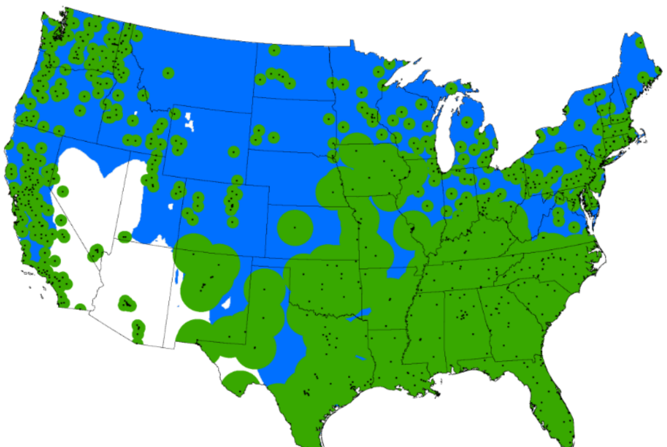


NASA Applied Sciences Architecture



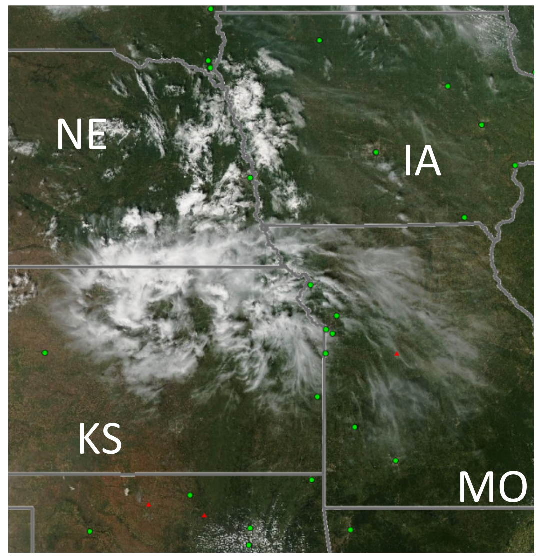
Improving EPA's AirNow Air Quality Index Maps with NASA Satellite Data

GROUND-BASED + SATELLITE COVERAGE OF AIR QUALITY



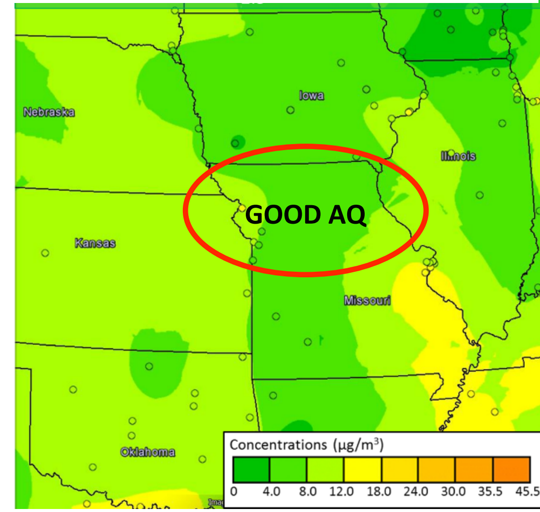
Green areas are ground-based $PM_{2.5}$ monitor coverage and the blue areas are AirNow Satellite-based $PM_{2.5}$ coverage. White areas have neither satellite nor ground based coverage.

Northern Missouri fires - Sept. 4, 2013

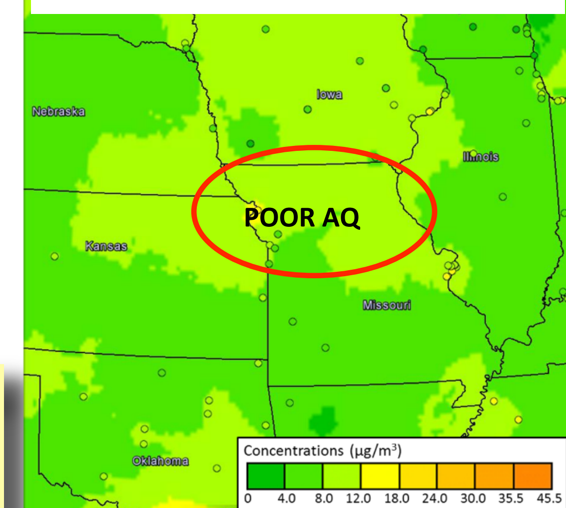


In the Missouri fires case (see http://www.youtube.com/watch?v=ycYp2-XtoxE) the addition of satellite data leads to the forecast of a poorer air quality index

PM2.5 FROM GROUND BASED DATA

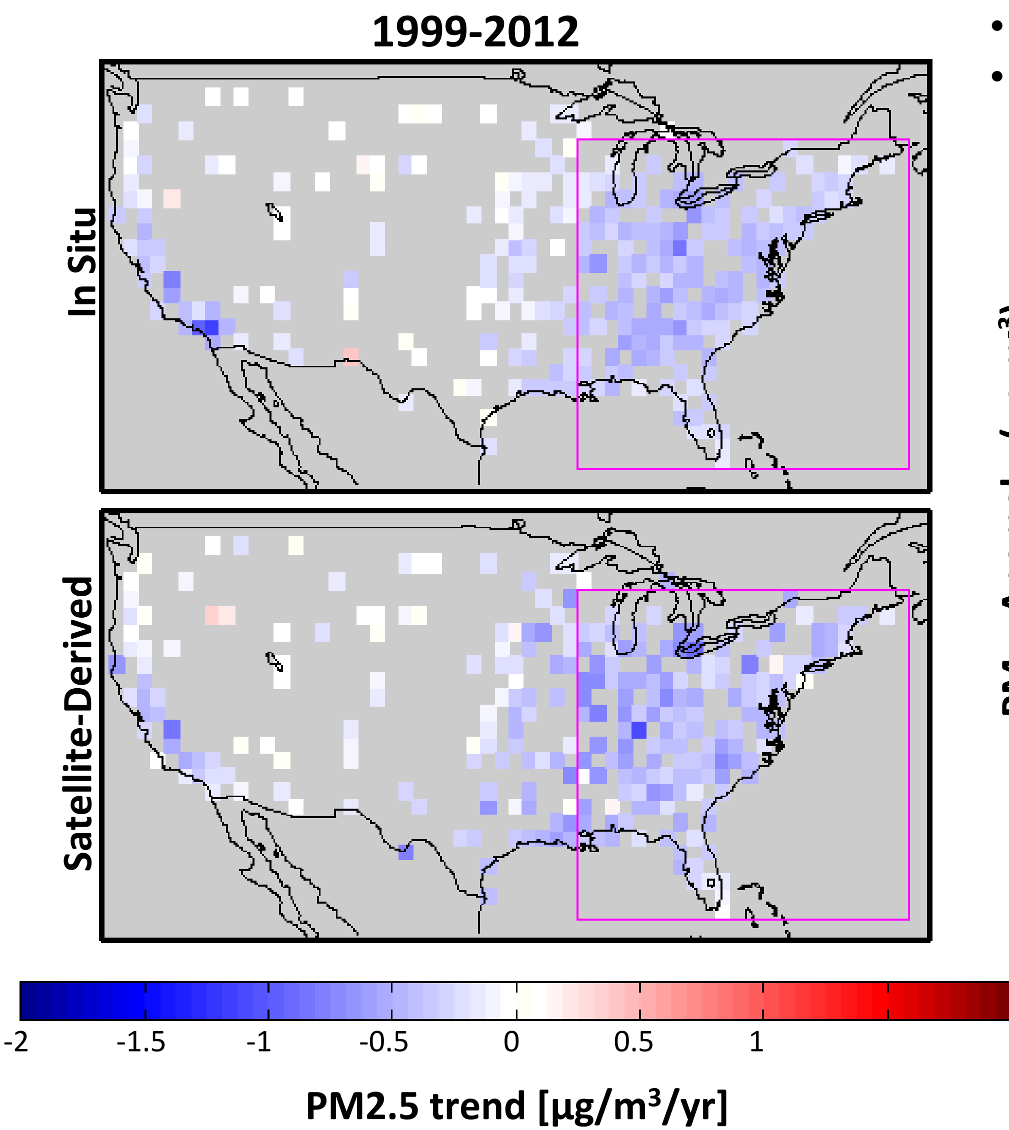


PM2.5 GROUND+SATELLITE DATA

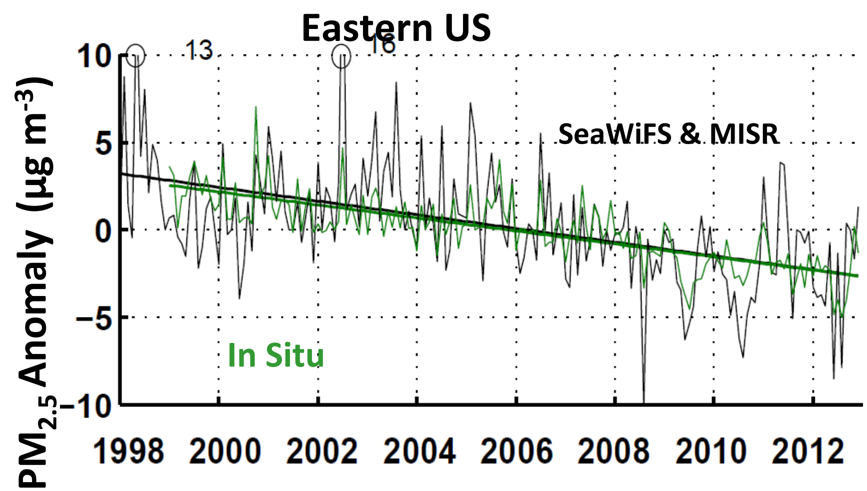


"This is the best tool I have seen so far that integrates satellite data with information from ground monitors."
Cassie McMahon,
Minnesota Pollution Control Agency

SeaWiFS and MISR AOD give insight into $PM_{2.5}$ trend



- Both instruments radiometrically stable
- CALIOP unavailable before 2006
  - cannot use on long-term AOD-$PM_{2.5}$ relationship

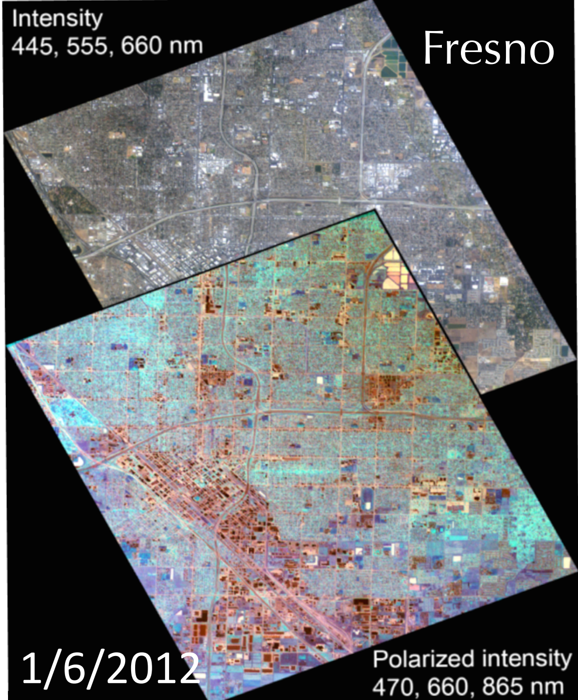


In Situ (1999-2012): 0.37 ± 0.06 $\mu g\ m^{-3}\ yr^{-1}$

Satellite-Derived (1999-2012): 0.36 ± 0.13 $\mu g\ m^{-3}\ yr^{-1}$

- Apply relative change to 2001-2010 mean $PM_{2.5}$ → consistent magnitude and trend

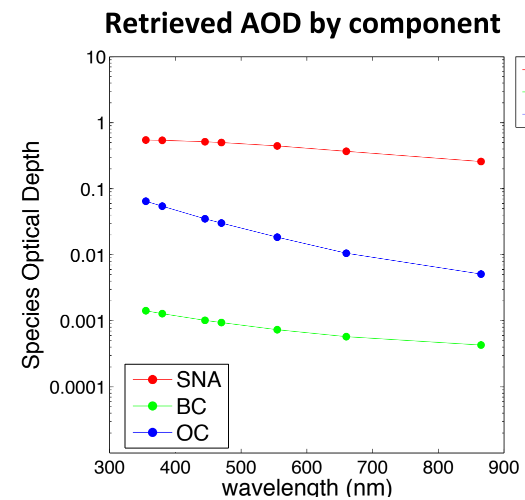
Boys et al., ES&T, 2014

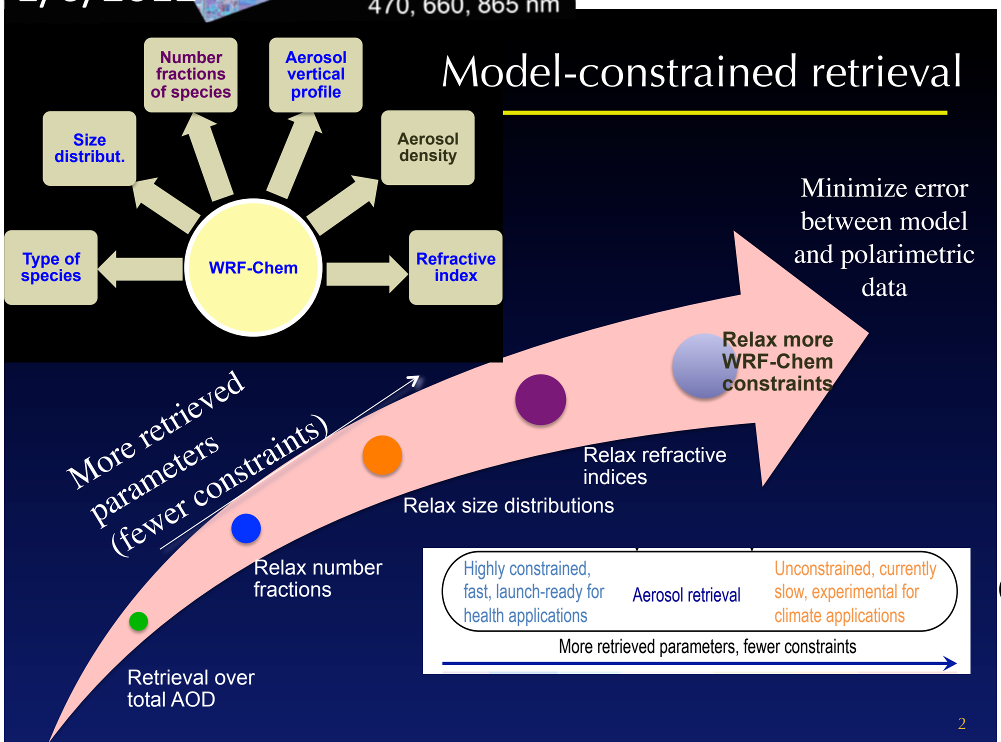


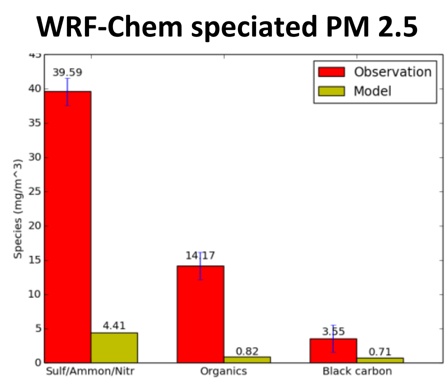
Applied Science Goal: *associate different types of airborne particles with adverse health outcomes*

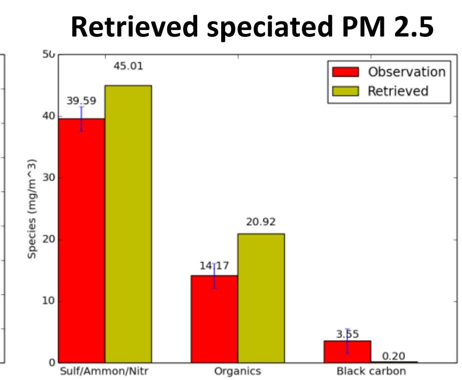
PM exposure is projected to become the world's leading environmental cause of premature deaths (Organisation for Economic Co-operation and Development, 2012)

Case study: Constraining $PM_{2.5}$ speciation over Fresno with AirMSPI polarimetric data









Multi-angular polarimetric observations combined with high-resolution WRF-Chem model predictions are promising tool for retrieving $PM_{2.5}$ by particle species

Main Proposed Objectives

Objective #1:

Bring an **applications-oriented perspective** so that the new products developed by PACE (*IOPs* a_{phyt}, a_{NAP}, a_{CDOM}, b_b, *atmospheric products*) are **linked to specific applications questions**.

Objective #2:

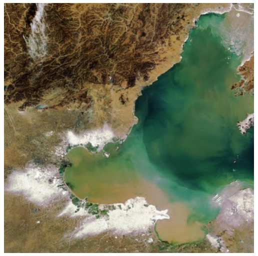
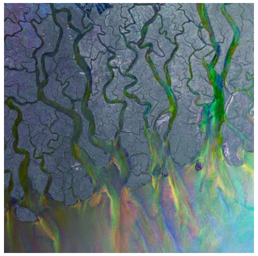
*Assess and **achieve consensus recommendations within the Science Team on the spectrum of applications we can address with PACE IOP** measurements and retrieval approaches.*

Objective #3:

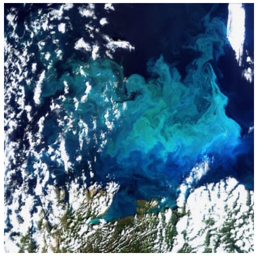
Working both with the users community and with other members of the PACE ST, assess what is the ***accuracy in IOPs needed for specific applications by the users*** and how this relates to the ***accuracy of the IOPs products & retrievals recommended by the PACE ST***.

Objective #4:

Address key issues related to applications from PACE, particularly ***requirements for spatial resolution in coastal waters and spatial coverage***, and ***how these related to the capabilities of IOPs retrievals*** recommended by the PACE ST.






Main Proposed Objectives

PACE Science Team Applications Sub-Group:

Steve Ackleson (CASE II waters)

Emmanuel Boss (global datasets)

Heidi Dierssen (cyanobacteria, suspended sediments, floating vegetation, floating plastics etc)

Deric Gray (NRL, military applications, diver visibility, etc)

Olga Kalashnikova (polarization, atmosphere)

Robert Levy (Air Quality, Atmospheric composition)

Dave Miller (NRL, military applications etc)

Ali Omar (Air Quality)

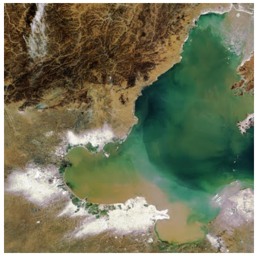
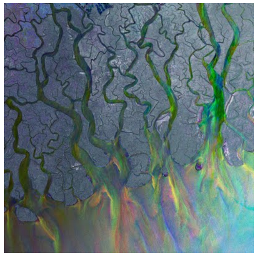
Mike Ondrusek (NOAA, operational, water quality, fisheries)

Steve Platnick (clouds, climate)

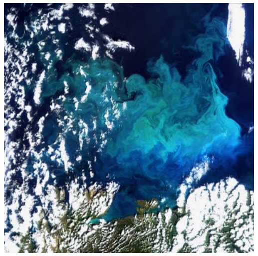
Lorraine Remer (aerosols, air-quality)

Mike Twardowski (WETLabs, wide range of users)

Maria Tzortziou (Coastal systems)



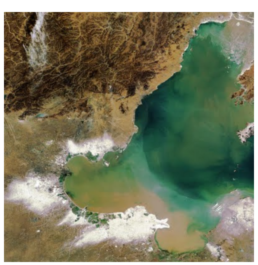



Main Proposed Objectives

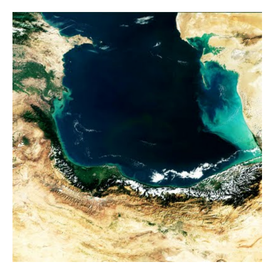
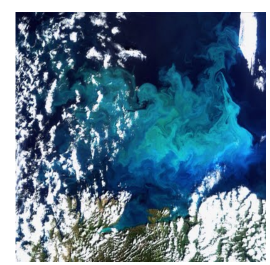
Highlight Atmosphere & Ocean Applications relevant to PACE

Relevant to PACE =

1. BOTH advanced ocean color AND atmospheric products
2. Spatial coverage: Global (both open ocean and coastal waters*)*
3. Spectral resolution: Hyper-spectral IOPs and atmospheric products
4. Spectral range: Extended UV-VIS-NIR with SWIR bands
5. Temporal Resolution: Daily retrievals
6. Spatial resolution: Threshold: 1 km (at nadir), Goal?






Application Question	Application Concept	Application Measurement Requirements	Applied Sciences Category	Potential Host Agency	Mission Data Product	
How do exchanges across the lan-ocean interface influence carbon and nutrient loadings, water quality, and ecosystem dynamics in coastal waters?	The EPA Safe and Sustainable Water Resources Research Program (SSWR) aims at developing core indicators of water resource integrity and sustainability as well as indicators of key drivers and pressures across a range of spatial and temporal scales for use in integrated assessments. Integration of satellite observations with field measurements and modeling tools is needed to demonstrate assessment of	Observations of Chla, Kd (water quality indicators) at: Spatial resolution (GSD local): Estuaries: ≤250m Coastal Waters: ≤500m Coverage needed (Width from coast to ocean): Minimum distance: 5.5 km Maximum distance: 22 km Latency 0.5-12 hours	Water Resources Oceans, Coasts, Great Lakes - Ecosystems and Human Health	Environmental Protection Agency [Blake Schaeffer, EPA]	chl-a, K_{PAR}, K_{490}	0. lat bre res Sp km an Alo res 25 inl co
How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability?	Assimilation of PACE satellite-derived optics and biogeochemical variables into operational seasonal-interannual models (Global Ocean Data Assimilation System / Coupled Forecast System (CFS); Real-Time Ocean Forecast System, RTOFS) for improving model skills and forecasting capabilities.	chl-a, K_{PAR}, K_{490} Spatial: 1 km Temporal: daily Coverage: Global Latency: 12 hours	Ecologial Forecasting	NOAA [Paul DiGiacomo, Cara Wilson NOAA]	chl-a, K_{PAR}, K_{490}	0. lat bre res Sp km an Alo res 25 inl co are
Oil Spill monitoring, response	NOAA's subsurface oil monitoring program uses various modeling and observational approaches (airborne, shipborne, ground-based, space-based measurements) to track oil spills: where the oil is going on the surface and under the sea, and what the consequences are to coastal communities, wildlife and the marine environment (e.g. Deepwater Horizon/BP Oil Spill).	Visible/true color imagery Spatial: < 300 m GSD (local) Temporal: 1 hr Coverage: coastal waters <185 km (<100 nmi); 50°N-10°N, 160°W-60°W Uncertainty: n/a Latency: 0.5-1 hour	Disasters Water Resourcces	NOAA [Paul DiGiacomo, Cara Wilson NOAA]	Visible/true color imagery	0. lat bre res Sp km an Alo res 25 inl co

Justification for ARL 3: Proof of Application Concept (Viability Established) Feasibility studies to assess the potential viability of and provide a proof-of-co

White Papers – PACE Applications

PACE MISSION APPLICATIONS - Harmful Algal Blooms

For example:
development of White Papers and posting these papers on PACE website
What "applications" would we like to highlight on PACE White Papers?

Upper Left: Harmful Algal Blooms kill fish, contaminate seafood and pollute our waters (Photo from NOAA/IOOS). Lower Left: Warning sign for cyanobacteria (Image Credit: J. Graham, USGS). Right: Satellite image of Lake Erie, showing the extent of the 2011 harmful algal bloom (the most severe in decades). Credit: MERIS/NASA; processed by NOAA/NOS/NCCOS.

Application Question/Issue: ***How can we better understand the causes and impacts (economic, cultural, environmental, human health) of Harmful Algal Blooms (HABs), and how can we improve monitoring and forecasting of the location and extent of HABs using ocean observations from space?***

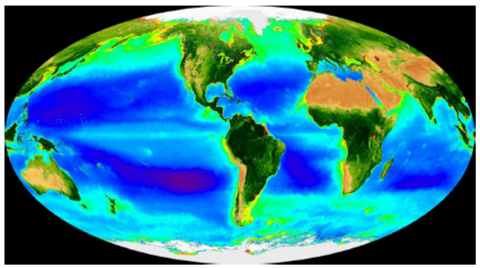
Who Cares and Why?

Coastal HAB events have been estimated to result in economic impacts in the United States of at least $82 million each year. The impacts of HABs range from environmental (e.g., alteration of marine habitats and impacts on marine organisms including endangered species), to human health (e.g., illness or even death through shellfish consumption, asthma attacks through

The NASA Response

The high (5-nm) spectral resolution measurements from PACE will allow regional algorithms to be developed for identifying and quantifying specific phytoplankton groups, thus allowing identification of HABs and tracking their evolution and variability over seasonal to interannual time scales. This information will lead to a highly sought-after understanding of environmental

Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) Mission Science Definition Team Report



October 16, 2012

PACE SDT Report, Oct 2012
PACE Mission Applications
Table 5-1, pg. 175-188

Table 5-1. PACE Mission: Major contributions to NASA application areas

PACE Mission Applications
Climate System
Carbon cycle research, mapping/assessment of carbon sources and fluxes, improved understanding of the biogeochemistry of elements involved in impacts and feedbacks of the climate system, improvement of climate models skills/forecasting capabilities, support of assessments, policy analyses, and design approaches to planning adaptation and responses to impacts of climate change.
Oceans, Coasts, Great Lakes - Ecosystems and Human Health
Fisheries and ecosystem health management, mapping of suspended sediment plumes, monitoring of water quality including transparency, eutrophication, hypoxic conditions, sediment resuspension and transport, impacts of river plumes on adjacent environments, patterns of connectivity, monitoring of oil spills and seeps, detection of harmful algal blooms (HABs), improved models of abundances of toxic pollutants, pathogens, bacteria that affect human and ecosystem health, monitoring of sea ice extent and passages, mapping of currents (applications to shipping industry, scheduling/fuel economy strategies).
Ecological Forecasting
Forecasting and early warnings of HABs, endangered species, vertebrates diversity and distribution, biodiversity, fisheries; PACE data assimilation into ocean models for improving model skills and forecasting capabilities.
Water Resources
Water quality and management of water resources in lakes, coastal areas and open oceans.
Disasters
Effects of hurricanes on ecosystems, oil-spills and oil seeps, tracking of volcanic ash, fires and impacts on ecosystems and human health.
Air Quality and Human Health*
Air quality monitoring, forecasting, management, climate change effects on public health and air quality, aerosols, clouds, volcanic ash/aviation hazard applications (see also Section 5.3).

* Many of the air quality applications would be significantly enhanced with an advanced multi-angle multi-spectral polarimetric imager.

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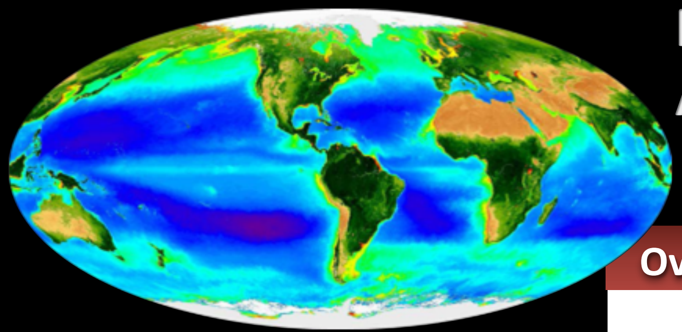


PACE Pre-Aerosol, Clouds, & ocean Ecosystem APPLICATIONS

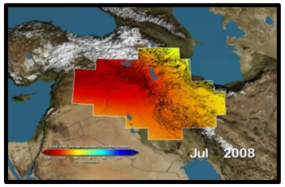
Overview

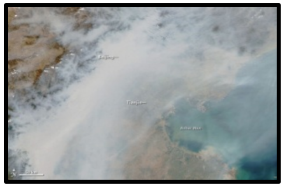
The overall goal of the PACE applications program is to identify potential user communities and areas of applications for this future NASA mission, to ensure that the product suite and delivery mechanisms maximize the usefulness of the data.

Relevance to NASA's Applied Sciences Program

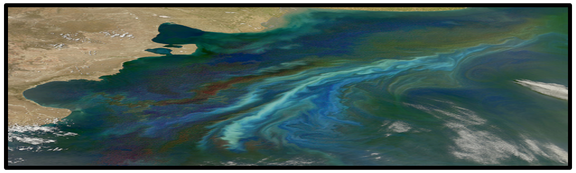
The NASA Applied Sciences Program (ASP) promotes and funds activities to discover and demonstrate innovative uses and practical benefits of NASA Earth science data, scientific knowledge, and technology.

The ASP, in coordination with the PACE Applications Working Group and the PACE Science Team will partner with public and private organizations on ways to apply data from PACE and its scientific findings in their decision-making activities and services, helping to improve the quality of life and strengthen the economy.



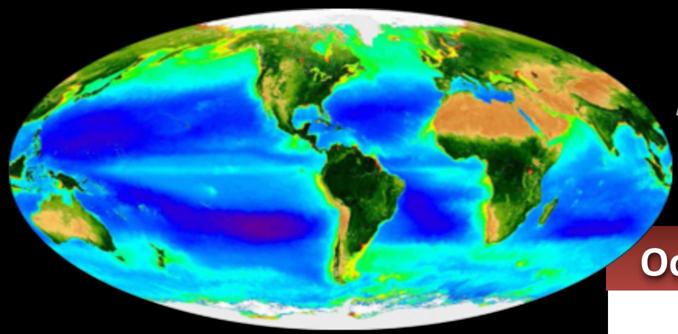


PACE observations will benefit a broad spectrum of public groups, including operational users in various tribal, local, state, federal, and international agencies; policy implementers; the commercial sector; scientists; educators; and the general public. The combination of high-quality, global atmospheric and oceanic observations provided by the PACE mission will provide direct benefits to society in the following major NASA application areas:



Oceans | Water Resources | Disasters | Climate

Ecological Forecasting | Human Health & Air Quality



PACE Pre-Aerosol, Clouds, & ocean Ecosystem
APPLICATIONS

Ocean

The PACE mission will make near-daily observations across the globe, with more frequent measurements at high latitudes. These observations will provide dynamic maps of a number of critical parameters that are needed to understand the location, status, variation, and trends in important ecosystem services.

Many applications in coastal, estuarine, and inland waters require high spectral and high spatial resolution space-based observations to resolve the complex optical signals and biogeochemical processes typically characterizing these environments. The medium (1 km) to high (250 to 500 m) spatial resolution observations from PACE will be particularly advantageous for research and societal applications in lakes, estuarine, and coastal environments, where environmental properties and the distribution of resources change rapidly over shorter distances than in the open ocean.

Climate System — Read More

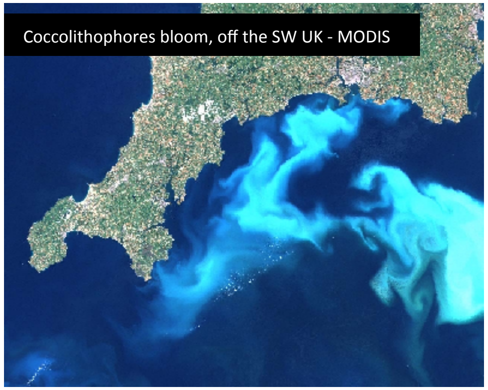
Oceans, Coasts, Great Lakes – Ecosystems and Human Health — Read More

Ecological Forecasting — Read More

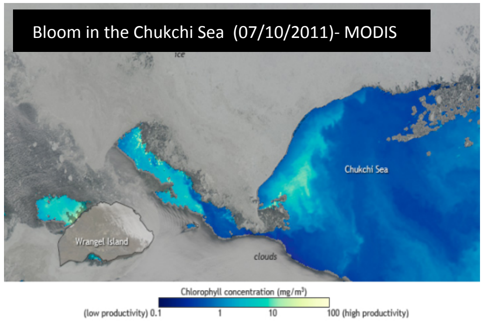
Water Resources — Read More

Disasters — Read More

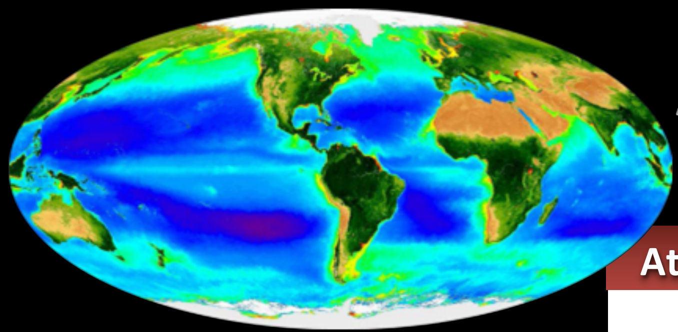
Gulf of Batabano, Cuba, after the passage of Hurricane Charley – MODIS 500m resolution



Coccolithophores bloom, off the SW UK - MODIS



Bloom in the Chukchi Sea (07/10/2011)- MODIS



PACE Pre-Aerosol, Clouds, & ocean Ecosystem
APPLICATIONS

Atmosphere

- PACE Home
- Mission Objectives
- Status Updates
- Science
- Applications
  - Overview
  - Ocean
  - Atmosphere
  - Applications Traceability Matrix (ATM)
  - Early Adopters Program
  - Applications Working Group
  - Data Products & User Tools
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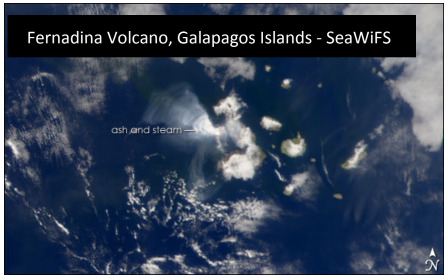
The PACE Mission focuses on understanding ocean ecology and the global carbon cycle and how it affects and is affected by climate change. These data will extend observations of ocean ecology, biogeochemical cycling, and ocean productivity begun by NASA in the late 1990s. To achieve these objectives, enhanced methods of atmospheric correction are required to account for the effects of absorbing and scattering aerosols in the Earth's atmosphere—signals that mask or alias ocean-color retrievals. These auxiliary atmospheric measurements will augment NASA's satellite observations of aerosols and clouds. Many of the applications outlined below presuppose an advanced multi-directional, multi-polarization, and multispectral imager (3MI).

Aerosol measurements with a 3MI-like instrument can augment retrievals by other NASA satellites and provide direct benefits to society. Potential applications of the PACE data include better assessments of local and regional air quality (a public health application) and improved characterization of hazards for issuing disaster warnings (a public safety application).

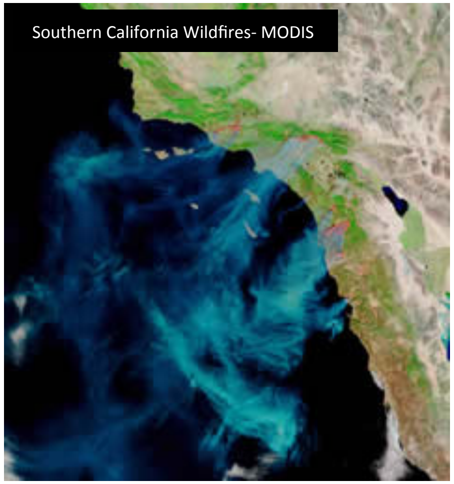
Improving Ambient Air Quality Forecasts, Monitoring and Trends
Read More

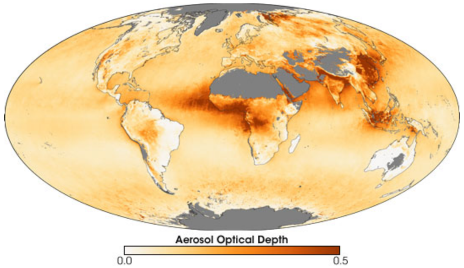
Improving Hazard Assessment and Aviation Safety
Read More

Fernadina Volcano, Galapagos Islands - SeaWiFS

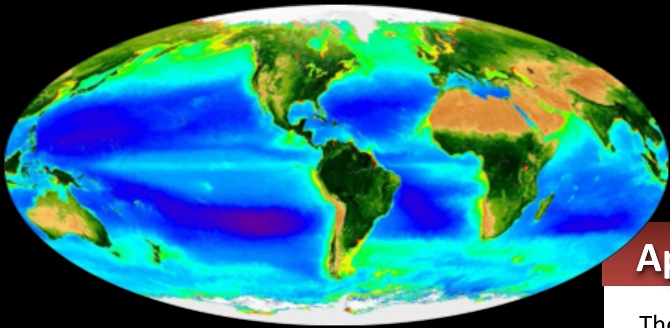


Southern California Wildfires- MODIS





MODIS Annual mean AOD for 2006



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Applications Traceability Matrix (ATM)

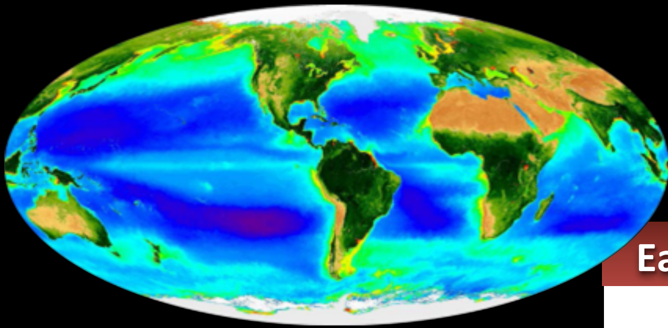
The mission's Applications Traceability Matrix (ATM) provides an overview of what potential applications, and includes information on application concepts and readiness levels, relevant data products and performance, identification of specific users, potential host agencies and points of contact.

The PACE ATM was developed by the PACE Applications Team, based on the information provided in the PACE Science Traceability Matrix (STM), following interactions with both the mission Science Definition Team and the Users' community.

Application Question	Application Concept	Application Measurement Requirements	Applied Sciences Category	Potential Host Agency	Mission Data Product	Projected Mission Performance	ARL	Ancillary Measurements
What is the air quality forecast of particulate matter (PM) predicted from PACE measurements of the aerosol optical depth (AOD) in regions where	The Environmental Protection Agency produces a daily air quality index which comprises both the ozone and particulate matter concentrations. In regions where there are no direct measurements of PM, satellite measurements of AOD can be used to	Observations of AOD at spatial resolutions of less than 1 km and latencies of less than 1 hour	Public Health and Air Quality	Environmental Protection Agency [James Szykman - EPA]	Aerosol Optical Depth	AOD within ± 0.02 at a horizontal resolution of 250 m	3	Aerosol vertical distributions Surface PM concentrations at a few locations
Volcanoes: What is the volcanic ash concentration during and after a volcanic eruption? Is there an impact on air quality as a result of a volcanic material deposited in coastal/populated regions?	Can we quantify this concentration using measurements collected to support PACE atmospheric corrections in coastal regions? Can we provide useful data to enable prudent aviation volcanic ash hazard mitigation policy and advisories?	Observations of AOD at spatial resolutions of less than 1 km and latencies of less than 1 hour	Disaster Mitigation Health and Air Quality	Federal Aviation Administration (FAA), US EPA, NOAA, International Civil Aviation Organization, Volcanic Ash Advisory Centers [Shobha Kondragunta- NOAA]	Aerosol Optical Depth	AOD within ± 0.02 at a horizontal resolution of 250 m	3	Aerosol vertical distributions Sulfur dioxide concentrations
How do exchanges across the lan-ocean interface influence carbon and nutrient loadings, water quality, and ecosystem dynamics in coastal waters?	The EPA Safe and Sustainable Water Resources Research Program (SSWR) aims at developing core indicators of water resource integrity and sustainability as well as indicators of key drivers and pressures across a range of spatial and temporal scales for use in integrated assessments. Integration of satellite observations with field measurements and modeling tools is needed to demonstrate assessment of sustainability and integrity of water	Observations of Chla, Kd (water quality indicators) at: Spatial resolution (GSD local): Estuaries: ≤250m Coastal Waters: ≤500m Coverage needed (Width from coast to ocean): Minimum distance: 5.5 km Maximum distance: 22 km Latency 0.5-12 hours	Water Resources Oceans, Coasts, Great Lakes - Ecosystems and Human Health	Environmental Protection Agency [Blake Schaeffer, EPA]	chl-a, K_{PAR}, K_{490}	•0.5 hour data latency, direct broadcast of 5 nm res. data •Spatial resolution of 1 km2 (±10%) at all angles across track •Along-track spatial resolution of 250 m x 250 m to <1 km2 for inland, estuarine, coastal, and shelf area	3	Aerosols (spectral shape, vertical distribution), NO2, O3 concentrations for atmospheric correction
How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability?	Assimilation of PACE satellite-derived optics and biogeochemical variables into operational seasonal-interannual models (Global Ocean Data Assimilation System / Coupled Forecast System (CFS); Real-Time Ocean Forecast System, RTOFS) for improving model skills and forecasting capabilities.	chl-a, K_{PAR}, K_{490} Spatial: 1 km Temporal: daily Coverage: Global Latency: 12 hours	Ecologial Forecasting	NOAA [Paul DiGiacomo, Cara Wilson NOAA]	chl-a, K_{PAR}, K_{490}	•0.5 hour data latency, direct broadcast of 5 nm res. data •Spatial resolution of 1 km2 (±10%) at all angles across track •Along-track spatial resolution of 250 m x 250 m to <1 km2 for inland, estuarine, coastal, and shelf area	3	Aerosols (spectral shape, vertical distribution), NO2, O3 concentrations for atmospheric correction
Oil Spill monitoring, response	NOAA's subsurface oil monitoring program uses various modeling and observational approaches (airborne, shipborne, ground-based, space-based measurements) to track oil spills: where the oil is going on the surface and under the sea, and what the consequences are to coastal communities, wildlife and the marine environment (e.g. Deepwater Horizon/BP Oil Spill).	Visible/true color imagery Spatial: < 300 m GSD (local) Temporal: 1 hr Coverage: coastal waters <185 km (<100 nmi); 50°N-10°N, 160°W-60°W Uncertainty: n/a Latency: 0.5-1 hour	Disasters Water Resourcces	NOAA [Paul DiGiacomo, Cara Wilson NOAA]	Visible/true color imagery	•0.5 hour data latency, direct broadcast of 5 nm res. data •Spatial resolution of 1 km2 (±10%) at all angles across track •Along-track spatial resolution of 250 m x 250 m to <1 km2 for inland, estuarine, coastal, and shelf area	3	Aerosols (spectral shape, vertical distribution), NO2, O3 concentrations for atmospheric correction

Categories: Disaster Mitigation, Ecological Forecasting, Health and Air Quality, Water Management, Agriculture, Climate, Energy, Oceans, and Weather

Justification for ARL 3: Proof of Application Concept (Viability Established) Feasibility studies to assess the potential viability of and provide a proof-of-concept for the application have been conducted.



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Early Adopters Program

*The **PACE Early Adopters (EA) Program** will promote applications research to provide a fundamental understanding of how PACE data products can be scaled and integrated into organizations' policy, business and management activities to improve decision-making efforts.*

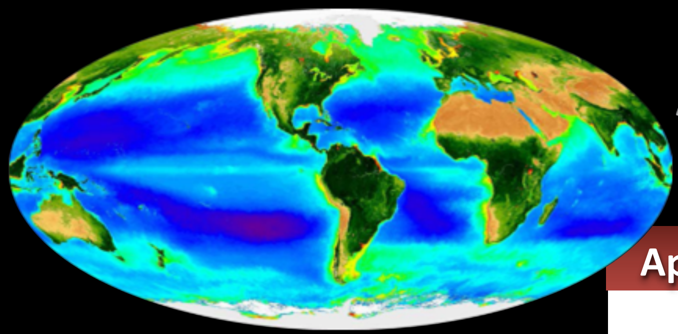
What is an "Early Adopter"? PACE Early Adopters are defined as those groups and individuals who have a direct or clearly defined need for PACE-like data, who have an existing application, new ideas for novel PACE-related applications, and who are planning to apply their own resources (funding, tools, personnel, facilities, etc) to demonstrate the utility of PACE data for their particular system or model. The Early Adopter will use preliminary data products that will become standard products for the PACE mission. The goal of this designation is to accelerate the use of PACE products after launch of the satellite by providing specific support to Early Adopters who commit to engage in pre-launch research that would enable integration of PACE data in their applications. Activities that emphasize an end-user connection will be most relevant. Projects would be completed with quantitative metrics prior to launch.

The **Early Adopter** will receive access to developmental products and interaction with the product developer enabling them to be among the first to integrate the new PACE products into their systems.

The **Science Team member** will gain a partner who can evaluate products and offer feedback from a functionality perspective as well as potential calibration and validation information.

Characteristics of the PACE EA program are:

- Each EA will be partnered with at least one PACE Science Team member who is developing a mission product that the EA would like to use/integrate into an application tool.
- The PACE EAs will participate in the implementation of the PACE Mission Applications Plan by taking lead roles in PACE applications research, meetings, workshops, and related activities.
- The EA program is an unfunded activity formalized through an early data access agreement (i.e., simulated PACE data) between the mission and the participating organization.
- Early Adopters will be nominated by the PACE Applications Working Group (AWG) from a pool of users after reviewing for relevance, availability of science team partners, and anticipated application.



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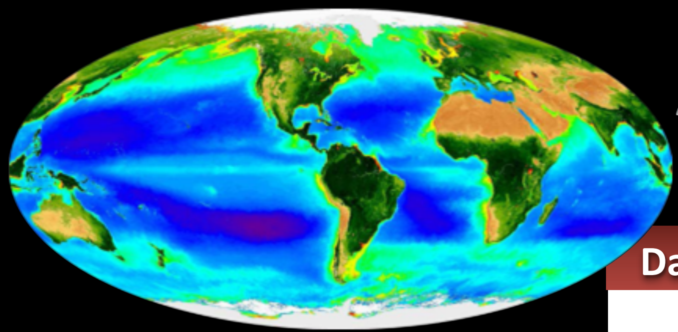
Applications Working Group

The **PACE Applications Working Group** (AWG) will actively participate and be involved with the mission concept teams and the mission science team in the development of the PACE mission and production/ distribution of products relevant to applications and scientific aspects of the mission that have a direct impact on applications. Currently, the PACE AWG consists of five members: the PACE Mission Applications Coordinators for ocean and atmosphere applications areas, the PACE Mission Applications Program Lead, and the PACE Mission Program Scientists.

The AWG will organize the relevant PACE applications communities and support organizations' and communities' efforts to imagine, articulate, and anticipate possible applications. The AWG will lead the mission's efforts to identify potential partnerships and collaborators and organize sufficient meetings/events/ workshops to support the applications communities at a national level for the mission.

The AWG will be the link between the mission and the applications communities relevant to the mission, communicating information about the mission to applications audiences across the range of relevant applications areas, and bringing the interests and concerns of the applications communities back to the mission development process at NASA. The AWG will present the needs of the applications communities at the science team meetings. It will advise relevant program managers at the Applied Science Program (ASP) about high impact PACE applications and publicize highlights of PACE applications.



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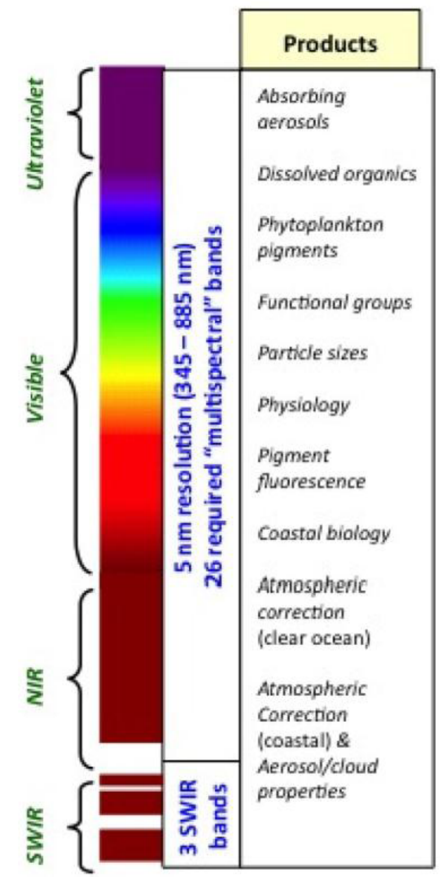
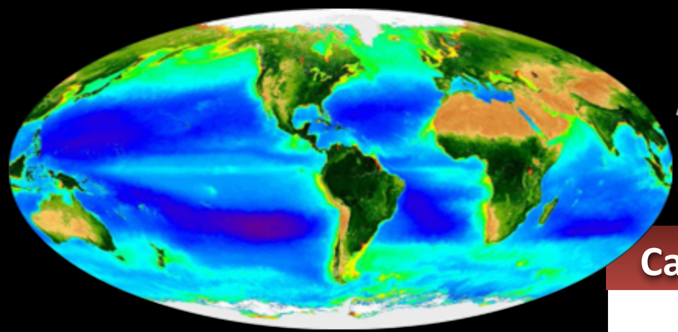
The **PACE mission** will provide the frequent global synoptic observations from space that are required to improve our quality of life by helping assess the status of our natural and man-made resources. The PACE mission will provide unprecedented spectral (hyperspectral) and spatial (250 m to 1 km) extended records on conditions that affect the ecology and biogeochemistry of our planet. The opportunity to provide polarimetric measurements with the PACE mission offers the possibility to further extend data records on clouds and aerosol composition and dynamics.

These measurements (see PACE Science Traceability Matrix, STM) will provide a unique capability to help understand changes that affect our ecosystem services; implement science-based management strategies of coastal, marine and inland aquatic resources; and support assessments, policy analyses, and design approaches to planning adaptation and responses to impacts of climate change *(from PACE STD Report: Pace Mission Applications).*

User Tools

PACE Data Products





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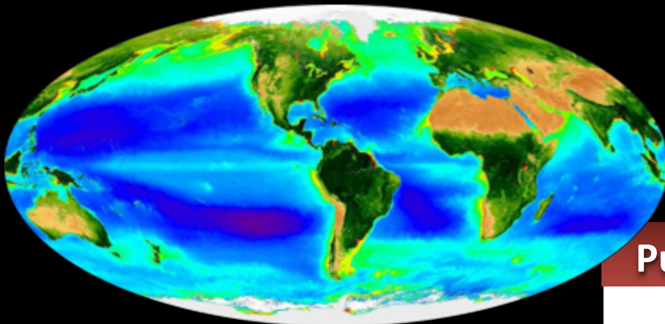

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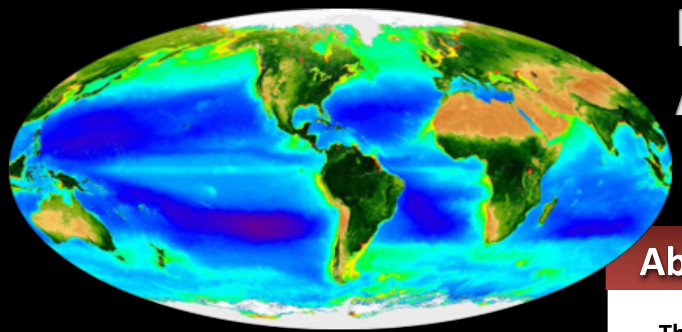
Publications/Presentations

- PACE SDT Report [Oct 16, 2012] – Applications Section on pg 175-187
  http://dsm.gsfc.nasa.gov/pace_documentation/PACE_SDT_Report_final.pdf

- Science Definition Team (SDT) Meeting [March 2012]
  http://dsm.gsfc.nasa.gov/PACEmtg2_Mar2012.html

- “Applications of Future NASA Decadal Missions for Observing Earth’s Land & Water Processes” by Luvall JC, Hook S, Brown ME, Tzortziou M, Carroll M, Escobar VM, Omar A, presented at the 2013 HyspIRI Science Symposium, NASA Goddard Space Flight Center, 29-30 May 2013.
  Provide link

- "NASA Future Ocean Color Satellite Missions and Applications to Studies of Extreme Weather Events and Impacts on Urban Coastal Ecosystems", by Tzortziou M., Mannino A., Omar A., presented at the Climate and Extreme Weather Impacts on Urban Coastal Communities Workshop, NOAA CREST / CCNY CUNY, 5-6 June 2013.
  Provide link



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About Us

The applications team consists of:

- Maria Tzortziou: DPA - Applications Coordinator for PACE Ocean Applications
- Ali Omar: DPA - Applications Coordinator for PACE Atmosphere Applications
- Woody Turner: PA - PACE Applied Science, NASA HQs
- Paula Bontempi: PACE Program Scientist, NASA HQs
- Hal Maring: PACE Program Scientist, NASA HQs

The PACE Applications Team was formed in 2012 to develop and facilitate the efforts of the PACE Applications Program to connect science to society. The Team operates under the direction of the PACE Program Scientists. Specific activities for the applications efforts include:

- Develop a list of applications foci for the PACE mission.
- Develop the PACE Applications Website.
- Develop the PACE Applications Traceability Matrix.
- Establish an Early Adopter program to demonstrate societally relevant applications to proposed data products.
- Establish an Applications Working Group to expand applications outreach.
- Attend and represent the PACE mission applications efforts at selected community meetings and workshops.
- Host interactive workshops and develop user tutorials to engage the community of practice and potential.
- Develop cross mission activities to establish connections between the PACE and other NASA missions communities

Contact us:

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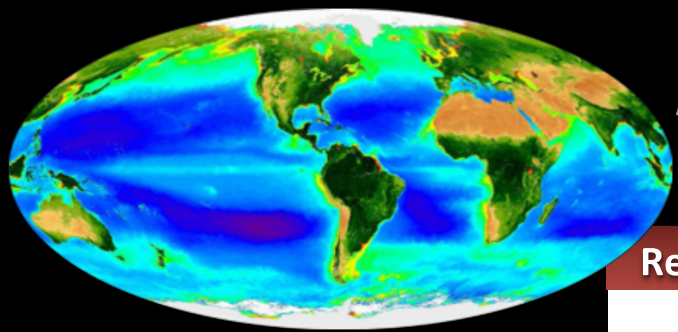

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Related Links

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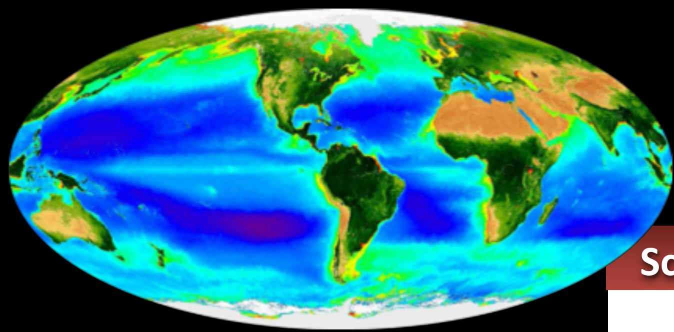
- ICESat-2 Applications: http://icesat.gsfc.nasa.gov/icesat2/apps-ov.php
- SMAP Applications: http://smap.jpl.nasa.gov/applications/
- GEO-CAPE Applications: http://geo-cape.larc.nasa.gov/applications.html

- NASA Decadal Survey Missions: http://dsm.gsfc.nasa.gov/index.html
- PACE Decadal Survey mission website: http://dsm.gsfc.nasa.gov/PACE.html
- ACE Decadal Survey mission website: http://dsm.gsfc.nasa.gov/ACE.html
- GEO-CAPE Decadal Survey mission website: http://geo-cape.larc.nasa.gov/
- HyspIRI Decadal Survey Mission website: http://dsm.gsfc.nasa.gov/HyspIRI.html
- ICESat II Decadal Survey Mission website: http://dsm.gsfc.nasa.gov/ICESat2.html

- NASA Science: http://science.nasa.gov/
- NASA Science Missions: http://science.nasa.gov/missions/
- NASA Carbon Cycle & Ecosystems: http://cce.nasa.gov/cce/index.htm
- International Ocean color Coordinating Group (IOCCG): http://www.ioccg.org/
- SERVIR: https://www.servirglobal.net/default.aspx
- DEVELOP: http://develop.larc.nasa.gov/



PACE Pre-Aerosol, Clouds, & ocean Ecosystem Mission

Science Traceability Matrix (STM)

PACE Threshold Ocean Mission Science Traceability Matrix (STM)

Science Questions

	Science Questions
1	What are the standing stocks, compositions, and productivity of ocean ecosystems? How and why are they changing?
2	How and why are ocean biogeochemical cycles changing? How do they influence the Earth system?
3	What are the material exchanges between land & ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?
4	How do aerosols influence ocean ecosystems & biogeochemical cycles? How do ocean biological & photochemical processes affect the atmosphere?
5	How do physical ocean processes affect ocean ecosystems & biogeochemistry? How do ocean biological processes influence ocean physics?
6	What is the distribution of both harmful and beneficial algal blooms and how is their appearance and demise related to environmental forcings? How are these events changing?
7	How do changes in critical ocean ecosystem services affect human health and welfare? How do human activities affect ocean ecosystems and the services they provide? What science-based management strategies need to be implemented to sustain our health and well-being?

Approach

Approach	Maps to Science Question
Quantify phytoplankton biomass, pigments, optical properties, key groups (functional/HABS), & estimate productivity using bio-optical models, chlorophyll fluorescence, & ancillary physical properties (e.g., SST, MLD)	1 4 2 5 3 6
Measure particulate &dissolved carbon pools, their characteristics & optical properties	2 3
Quantify ocean photobiochemical & photobiological processes	2 4
Estimate particle abundance, size distribution (PSD), & characteristics	1 3
Assimilate PACE observations in ocean biogeochemical model fields to evaluate key properties (e.g., air-sea CO_2 flux, carbon export, pH, etc.)	2 4
Compare PACE observations with field- and model data of biological properties, land-ocean exchange, physical properties (e.g., winds, SST, SSH), and circulation (ML dynamics, horizontal divergence, etc)	3 4 5 6
Combine PACE ocean & atmosphere observations with models to evaluate ecosystem-atmosphere interactions	4
Assess ocean radiant heating and feedbacks	5
Conduct field sea-truth measurements & modeling to validate retrievals from the pelagic to near-shore environments	1 4 2 5 3 6
Link science, operational, & resource management communities. Communicate social, economic, & management impacts of PACE science. Implement strong education & capacity building programs.	7

Measurement Requirements

- water leaving radiance at 5 nm resolution from 350 to 800 nm
- 10 to 40 nm wide atmospheric correction bands at 350, 820 (or 940), 865, 1240, 1640, and 2130 nm
- characterization of instrument performance changes to ±0.2% in first 3 years & for remaining duration of the mission
- monthly characterization of instrument spectral drift to 0.3 nm accuracy
- daily measurement of dark current & a calibration target/source with its degradation known to ~0.2%
- Prelaunch characterization of linearity, RVVA, polarization sensitivity, radiometric & spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric & band-to-band stability, bidirectional reflectance distribution, & relative spectral response
- overall instrument artifact contribution to TOA radiance of < 0.5%
- image striping to < 0.1% in calibrated top-of-atmosphere radiances
- crosstalk contribution to radiance uncertainties of 0.1% at L_{typ}
- polarization sensitivity $\leq$ 1%
- knowledge of polarization sensitivity to $\leq$ 0.2%
- no detector saturation for any science measurement bands at L_{max}
- RVVA of < 5% for entire view angle range & < 0.5% for view angles differing by less than 1°
- Stray light contamination for the instrument < 0.2% of L_{typ} 3 pixels away from a cloud
- Out-of-band contamination < 0.01 for all multispectral channels
- Radiance-to-counts characterized to 0.1% over full dynamic range
- Global spatial coverage of 1 km x 1 km (±0.1 km) along-track
- Multiple daily observations at high latitudes
- View zenith angles not exceeding ±60°
- Standard marine atmosphere, clear-water $[r_w(l)]_N$ retrieval with accuracy of max[5% , 0.001] over the wavelength range 400 – 710 nm
- SNR at L_{typ} for 1 km² aggregate bands of 1000 from 360 to 710 nm; 300 @ 350 nm; 600 @ NIR bands; 250, 180, and 15 @ 1240, 1640, & 2130 nm
- Absolute calibration to 2% pre-launch and 5% on-orbit (before vicarious calibration)
- 3 hour data latency and direct broadcast of aggregate spectral bands
- Simultaneity of 0.02 second

Implementation Requirements

Vicarious Calibration: Ground-based R_{rs} data for evaluating post-launch instrument gains. Features: (1) Spectral range = 350 - 900 nm at $\leq$ 3 nm resolution, (2) Spectral accuracies $\leq$ 5%, (3) Spectral stability $\leq$ 1%, (4) Deploy = 1 yr prelaunch through mission lifetime, (5) Gain standard errors to $\leq$ 0.2% in 1 yr post-launch, (6) Maintenance & deploy centrally organized, & (7) Routine field campaigns to verify data quality & evaluate uncertainties

Product Validation: Field radiometric & biogeochemical data over broad possible dynamic range to evaluate PACE science products. Features: (1) Competed & revolving Ocean Science Teams, (2) PACE-supported field campaigns (2 per year), (3) Permanent/public archive with all supporting data

Ocean Biogeochemistry-Ecosystem Modeling

- Expand model capabilities by assimilating expanded PACE retrieved properties, such as NPP, IOPs, & phytoplankton groups & PSD's
- Extend PACE science to key fluxes: e.g., export, CO_2, land-ocean exchange

Platform Reqmts.

- 2-day global coverage to solar zenith angle of 75°
- Sun-synchronous polar orbit with equatorial crossing time between 11:00 and 1:00
- Maintain orbit to ±10 minutes over mission lifetime
- Mitigation of sun glint
- Mission lifetime of 5 years
- Storage and download of full spectral and spatial data
- Monthly lunar observations at constant phase angle through Earth observing port
- System-level pointing accuracy of 2 IFOV and knowledge equivalent to 0.1 IFOV over the full range of viewing geometries
- System-level pointing jitter accuracy of 0.01 IFOV or less between any adjacent spatial samples
- Spatial band-to-band registration of 80% of one IFOV between any two bands, without resampling

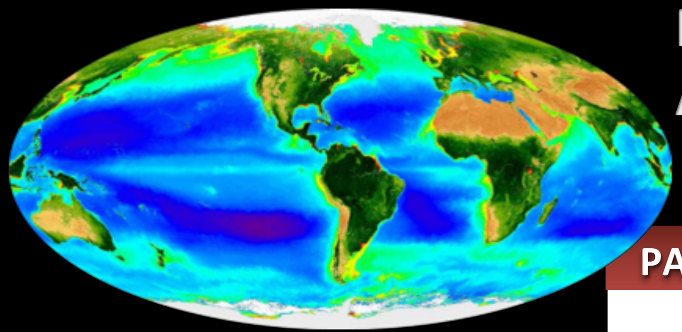
Other Needs

Capability to reprocess full data set 1 – 2 times annually

Ancillary data sets from models missions, or field observations:

Measurement Requirements
(1) Ozone
(2) Water vapor
(3) Surface wind velocity and barometric pressure
(4) NO_2

Science Requirements
(1) SST
(2) SSH
(3) PAR
(4) UV
(5) MLD
(6) CO_2
(7) pH
(8) Ocean circulation
(9) Aerosol deposition
(10) run-off loading in coastal zone



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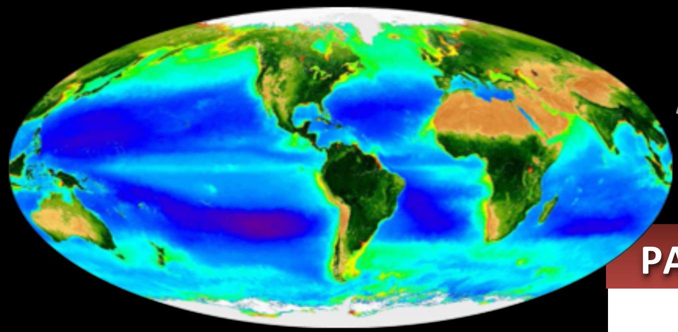
Climate System
Carbon cycle research, mapping/assessment of carbon sources and fluxes, improved understanding of the biogeochemistry of elements involved in impacts and feedbacks of the climate system, improvement of climate model skills/forecasting capabilities, support of assessments, policy analyses, and design approaches to planning adaptation and responses to impacts of climate change.
Oceans, Coasts, Great Lakes - Ecosystems and Human Health
Fisheries and ecosystem health management; mapping of suspended sediment plumes; monitoring of water quality, including transparency, eutrophication, hypoxic conditions, sediment resuspension and transport; impacts of river plumes on adjacent environments; patterns of connectivity; monitoring of oil spills and seeps; detection of harmful algal blooms (HABs); improved models of abundances of toxic pollutants, pathogens, bacteria that affect human and ecosystem health; monitoring of sea ice extent and passages; mapping of currents (applications to shipping industry, scheduling/fuel economy strategies).
Ecological Forecasting
Forecasting and early warnings of HABs, endangered species, vertebrates diversity and distribution, biodiversity, fisheries; PACE data assimilation into ocean models for improving model skills and forecasting capabilities.
Water Resources
Water quality and management of water resources in lakes, coastal areas and open oceans.
Disasters
Effects of hurricanes on ecosystems, oil-spills and oil seeps; tracking of volcanic ash, fires and impacts on ecosystems and human health.
Air Quality and Human Health*
Air quality monitoring, forecasting, management; climate change effects on public health and air quality; aerosols, clouds, volcanic ash/aviation hazard applications (see also section 5.3).

* Many of the air quality applications would be significantly enhanced with an advanced multi-angle multi-spectral polarimetric imager.



PACE Pre-Aerosol, Clouds, & ocean Ecosystem APPLICATIONS

PACE applications

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TBD